HEXOS – Humidity Exchange Over the Sea: Scientific Plan

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by

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Frontispiece. The Meetpost Noordwijk (MPN)

ABSTRACT

Smith, S. D., Katsaros, K. B., and Oost, W. A. 1983. HEXOS - Humidity Exchange Over the Sea: Scientific Plan. Can. Tech. Rep. Hydrogr. Ocean Sci. 21: v + 47 p.

The parameterization of evaporation from the sea surface is recognized as an area of importance in the understanding of climate in which substantial progress is needed. A set of six questions is posed and an international series of co-ordinated experiments is proposed.

RÉSUMÉ

Smith, S. D., Katsaros, K. B., and Oost, W. A. 1983. HEXOS - Humidity Exchange Over the Sea: Scientific Plan. Can. Tech. Rep. Hydrogr. Ocean Sci. 21: v + 47 p.

La parameterisation de l'évaporation de la surface de la mer est un problème important concernant la compréhension scientifique du climat, et où des progrès considérables sont exigés. Un ensemble de six questions est posé, et une série internationale d'expériences coordonnées est proposée.

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REVISED HEXOS PROGRAMME

INTRODUCTION

The evaporation of water from the ocean is an important physical process which must be parameterized in climate, synoptic, mesoscale, boundary layer and oceanic numerical models. Because of the increasing contribution of sea spray and whitecap-produced water droplets, the humidity exchange is expected to be strongly nonlinear in wind speed. As a consequence of this nonlinearity, it is believed that high wind speed conditions, though brief in duration, may contribute a disproportionate amount to the vertical water flux budget. The investigation of these phenomena requires the development of new, rugged sensors that can operate in the hostile marine environment, the advancement of theoretical droplet-vapor boundary layer models and a program of measurements encompassing the entire range from laboratory simulations to deep water, open ocean field experiments.

During the 1981 HEXOS Workshop the Dutch Meetpost Noordwijk (Measuring station Noordwijk) was suggested as one of the possible sites for part of the HEXOS experiment. This suggestion has been followed and the 1986 HEXOS Main Experiment (HEXMAX) is to be held at the Meetpost Noordwijk (MPN), despite some disadvantages: the water is only 18 m deep, high wind speeds are rare, and the accommodations on the platform are rather small.

Questions to be Addressed by HEXOS Programme

The Humidity Exchange over the Sea (HEXOS) programme proposes to study processes of turbulent humidity exchange over the ocean at moderate (10 - 15 m/s) and high (> 15 m/s) wind speeds, and to find parameterization formulas required for climatic, oceanographic, and meteorological studies, based on both field and laboratory measurements taken over a wider range of conditions than now available. The present state of knowledge has been reviewed and six specific questions are posed (Smith and Katsaros, 1981, BIO Report 81-17, Section 3.5; this report is referred to hereafter as SK81), while recognizing that a single experiment may not definitively answer all of these:

(1) How does the evaporation coefficient depend on wind speed, sea state, and stability?

(2) Can surface-layer bulk formulations be applied at high wind speeds? If

so, at what height should the humidity be measured?

(3) Can we demonstrate experimentally an expected dependence of evaporation on wind stress, stability, wave breaking, and spray droplet distribution?

(4) How well do 'dissipation' measurements from a ship and from a fixed platform estimate evaporation (and sensible heat flux and wind stress), as compared with direct eddy correlation measurements?

(5) Can eddy correlation measurements be satisfactorily corrected for flow distortion by a fixed platform?

(6) Can fast-response humidity sensors be operated in marine conditions for extended periods of time? Which types are most successful, and could they be adapted for longer-term operation on unmanned platforms?

An international group met at Bedford Institute of Oceanography in April, 1981 with NATO sponsorship to formulate the above questions and to draw up an experimental plan to make progress toward answering them. This plan outlined an interdisciplinary, multi-national experiment which was originally proposed to be held at the German Nordsee Platform in the fall of 1983.

Following a meeting of several of the HEXOS participants during the First International Conference on Meteorology and Air-Sea Interaction of the Coastal Zone, held at The Hague, May 1982, correspondence with HEXOS participants and informal meetings during the Joint Oceanographic Assembly, Halifax, August 1982, a revised programme is proposed. The present HEXOS schedule calls for the following work:

(A)	1983	Wind tunnel flow distortion study
(B)	1983-1986	Development of boundary layer model incorporating spray
(C)	1984	U. S. Pilot experiment
(D)	1984	European pilot experiment
(E)	1985	Wave tank/wind tunnel experiment (HEXIST)
(F)	1986	HEXOS main experiment (HEXMAX)

The main experiment is to be held at the Dutch platform Meetpost Noordwijk (Measuring Station Noordwijk) in the fall. In measuring eddy fluxes from a relatively bulky platform the question of errors introduced by flow distortion must be

investigated, and so the first work to be done in HEXOS is a flow distortion study. It is encouraging to note that Oost (1982) has measured wind stress at the Meetpost Noordwijk using both sonic and pressure anemometers and has obtained wind drag coefficients which are not significantly different from other recent measurements over the sea, even without corrections for flow distortion.

The host agency, KNMI, has made a definite commitment to HEXOS. We do not yet have a definite commitment of a ship equipped to carry out the required ship-based measurements, but the U.S. Naval Postgraduate School group plans to apply for ship time through the U.S. Naval Oceanographic Command, and there is also a possibility of participation of German and British ships.

Even after the six experiments proposed here, additional work will still be required before all the questions are answered definitively.

A. HEXOS Flow Distortion Study of Model of Meetpost Noordwijk

Principal Investigator: J.A.B. Wills

Location: National Maritime Institute, Teddington, England (NMI)

Purpose: (Question 5) Determine feasibility of eddy correlation measurements based on measurements of mean flow, turbulence, and Reynolds stress around a model platform (including planned structural additions) in a wind tunnel with a simulated atmospheric boundary layer. Determine optimum sensor locations accessible with a reasonable length of boom, for various wind directions. Determine correction factors for Reynolds stress as a function of sensor location and wind direction.

Date: 1983

Instrumentation and Methods: The existing 1/25 scale model of Meetpost Noordwijk will be brought up to date and mounted in the NMI 2.4 m x 4.8 m atmospheric simulation tunnel, adjusted for a marine boundary layer. Measurements of mean velocities and momentum fluxes will be made with hot wires at suitable positions close to the model and in the empty tunnel for various wind directions, to yield values of flow distortion for the velocities and fluxes, and enable choices to be made of measurement positions and corrections to be made for those positions.

B. Numerical Studies of the Sensitivity of the Marine Boundary Layer to Spray

Principal Investigators: K. B. Katsaros, R. A. Brown, C. Fairall, K. Davidson, E. C. Monahan.

Location: Authors' Institutions

Date: 1983 - 1986

Methods: Two separate avenues will be taken initially, one at the University of Washington (UW), the other a joint effort between Pennsylvania State University and the Naval Postgraduate School (NPGS). In the University of Washington effort, the emphasis is on the role of humidity in the effect of stratification on the boundary layer; in the Penn State-NPGS effort, the emphasis is on entrainment at the top of the boundary layer. Both studies will extend existing models, paying particular attention to the formulation of the surface boundary conditions when sea spray is present. The ultimate goal is to merge the two models, since the phenomena studied are interactive.

At the University of Washington, the one-dimensional marine atmospheric boundary layer model of Brown and Liu (1982) will be extended to include the influence of evaporating sea spray on the profiles of temperature, humidity and wind. This model parameterizes the fluxes in the surface and Ekman layers and the effects of wind speed and stratification on the momentum flux.

The stratification effect is known to be important in both layers. At present, the influence of humidity on the stratification is represented by a rough parameterization (Liu et al., 1979). Its effect is found to be significant when layer buoyancy is near neutral. We propose to develop the parameterization of humidity flux to incorporate the HEXOS measurements of vapour and droplets. This will lead to better bulk parameterizations of both heat and humidity flux through the marine atmospheric boundary layer.

The Fairall-Davidson effort involves the modification of the NPGS cloud-top entraining mixed layer model to include white cap produced sea spray coupled to the temperature and humidity. Particular emphasis will be given to incorporating the spray from breaking waves in the surface boundary conditions. Ling and Kao (1976) made a pioneering effort in

modelling the coupling of spray and humidity profiles with the temperature profile in the marine atmospheric boundary layer. Since this work there have been new developments in the understanding of the turbulent transfer and effects of stratification, which are incorporated in the model of Brown and Liu (1982). New formulations of the spray production as a function of wind speed have also appeared (e.g., Monahan, 1982; Fairall and Larsen, 1983). The model results will provide feedback to the HEXOS measurement program. Sensitivity studies will reveal the significance of variations in the basic parameters, which parameters are the most important, and the required accuracies of measurements. One can ask questions of the model such as: Does improvement in humidity measurement improve the prediction of moisture flux, or is temperature accuracy a more significant limiting factor in the parameterization?

When the one-dimensional model is acceptable, extension of the parameterizations of heat, moisture and momentum fluxes to a mesoscale field model is straightforward. Such models are increasingly important to weather analysis, global heat flux and climatological studies. A prototype mesoscale field model is in existence (Brown, 1982). The mesoscale model will allow testing of the new parameterizations against existing large-scale field measurements from the Joint Air Sea Interaction (JASIN) Experiment and from the Storm Transfer Response Experiment (STREX).

One aim of this work will be to help to develop the sampling strategy for the field experiment, HEXMAX, which will be carried out on the Dutch platform Noordwijk and with the British C-130 aircraft. For instance, we need to evaluate at what minimum height a measure of the vapour flux includes both the evaporative and all of the spray droplet components. How this height might depend on the wind speed (wave breaking) stratification, inversion height, and the dryness of the upper part of the boundary layer will be investigated. Conversely, data from the pilot experiments (Sections C and D) and the main experiment (Section F) will be used in the development of the models.

C. HEXOS San Nicolas Island Experiment (SNI 84)

Principal Investigators: C. W. Fairall, K. B. Katsaros, K. L. Davidson, T. V. Blanc and S. E. Larsen

Purpose: (Questions 4, 5, 6). Test and compare instruments recently developed to measure humidity, fluxes and particles in the heavy sea spray regime. The experiment will also investigate flow distortion effects on dissipation and eddy fluxes and the interaction of surface produced droplets with the mean and turbulent temperature and humidity fields.

Location: San Nicolas Island, California (see Appendix 2)

Date: SNI 84 is presently planned for the Spring of 1984, preferably in April or May. The exact dates will be determined by the availability of the R/V ACANIA and SNI range scheduling. The spring period is chosen to maximize the probability of wind speeds greater than 10 m/s.

Objectives: This experiment is conceived as a pilot study to test and compare equipment and methods required for humidity (vapour and liquid) flux measurements over the ocean under whitecap conditions. SNI was chosen because: 1) the surf zone provides a steady source of natural seawater droplets; 2) reasonably high winds can be counted on in the spring; 3) the deep water nearby permits close approach of the Naval Postgraduate School research vessel ACANIA; and, 4) good support facilities and an excellent tower sited at the high tide mark are available (Appendix 2). SNI 84 will permit an attack on questions (4), (5) and (6) of the HEXOS Programme without the logistic difficulties of working on an offshore tower. Heavy droplet densities will be continuously available rather than only during periods of climatologically intermittent periods of very high winds. New equipment planned for shipboard deployment in the main HEXOS experiment (1986) will be tested on the R/V ACANIA in realistic conditions of ship motion.

Specific objectives are listed below:

(1) Testing and Comparison of New Devices

(a) Fast humidity: droplet protected Lyman-alpha humidiometer, and droplet protected wet microthermocouple.

(b) Fast velocity: hot wires, 3-axis minipropellers, minicup and sonic anemometers.

(c) Fast temperature: sonic anemometer, droplet protected microthermistor and microthermocouple.

(d) Mean humidity: sulphuric acid latent heat release (SALTHER) device.

(e) Droplet size and number concentration: single particle optical droplet sensor, PMS particle/droplet systems.

(2) Flow Distortion

By comparing R/V ACANIA and SNI tower measurements, the accuracy of flow distortion models will be evaluated for both mean flow profiles and dissipation rates.

(3) Dissipation Method

The dissipation method fluxes will be compared with the direct eddy correlation values.

(4) Droplet Effects

The interaction of droplets, droplet fluxes and mean scalar fields and fluxes will be evaluated and available for comparison with theory (see Section B).

Facilities: The NRL tower on SNI (Appendix 2) and the R/V ACANIA (Appendix 4) are the basic facilities to be employed. Both facilities are equipped with a full suite of micro-meteorological equipment and data acquisition systems. Complete and detailed descriptions are available (Blanc, 1981; Schacher et al, 1980).

D. HEXOS Meetpost Noordwijk Pilot Experiment

Co-ordinator: W. A. Oost Visiting Scientist: K. B. Katsaros

Purpose: In order to check the possibilities and limitations of the site for the main experiment HEXMAX, the planned fall 1984 Royal Netherlands Meteorological Institute (KNMI) series of flux and wave measurements has been expanded into a HEXOS pilot experiment.

Scientific Objectives: This is a technical and scientific test for HEXMAX and as such has a bearing on all HEXOS questions except for Question 2; high wind speeds are not anticipated. The size of this pilot experiment is limited both in the number of participants and the facilities. The aim is mainly to identify problem areas and provide provisional results for HEXMAX. Special attention

will be given to the fourth and fifth question of the HEXOS programme:

- How well do dissipation measurements estimate fluxes compared with direct eddy correlations?
- Can eddy flux measurements be satisfactorily corrected for flow distortion by a fixed platform?

The last question bears a direct relationship to the wind-tunnel flow distortion study.

Technical Objectives: Test the reliability of measuring systems for HEXMAX; investigate the problems of physically installing and operating a number of measuring systems on the platform at the same time; investigate interference problems of instruments mounted on a new instrument boom.

Participation: KNMI will certainly be involved as this is in fact an expansion on the experiment already planned, and the University of Washington (UW) and Bedford Institute of Oceanography (BIO) will participate. Scientists involved are K. Katsaros (UW), W. A. Oost (KNMI), C. Kraan, W. Kohsiek (KNMI), S. D. Smith (BIO), R. J. Anderson (BIO), and D. N. Asimakopoulos, University of Athens. One or two flights of the BMO instrumented aircraft are proposed; the scientist involved is D. Carson.

KNMI instruments to be used on the platform will be: pressure anemometer sonic anemometer (Kaijo-Denki DAT-300); capacitive wave height sensor; wet and dry bulb psychrometer (response frequency 0.5 and 5 Hz respectively); and breaking wave detector (to be developed).

UW instruments include a new Gill-anemometer system for eddy fluxes, shielded dry-and wet-bulb thermocouples, a PRT 5 radiation thermometer for surface skin temperature, and a short-and long-wave radiation station (Eppley pyranometer, Eppley pyrgeometer, and a Schultze pyrradiometer). The Bedford Institute of Oceanography (BIO) will measure eddy fluxes of momentum, heat and water using a sonic and/or a thrust anemometer, a microbead thermistor, a spray-protected Lyman-alpha humidiometer, and possibly an infrared humidiometer. The University of Athens will study the flow distortion field using acoustic sounding instruments.

In addition to these instruments sensors present for routine meteorological and oceanographic data are listed in the description of MPN.

Other groups wishing to participate are expected to conform to the

following:

- Instruments must be mounted to the boom or other parts of the platform without modifications to existing structures or welding.

- Cables for instruments mounted at the tip of the boom must have a length of at least 45 m to reach the control room.

- Not more than two people of a participating group can stay on the platform at the same time (the number of groups, besides the KNMI/UW party, will be limited to two; changes are possible at the weekends).

- Each participating group is responsible for its own funding for travel and shipping to and from the Netherlands and for living expenses while on shore. The mounting of instruments will be arranged in consultation with the co-ordinator. Transportation to and from the platform and meals, etc., on the platform will be centrally organized, but this does not include extra trips on behalf of individual participants.

Date: October 29 - November 16, 1984. Instruments for the platform must be available by October 1 for transport to MPN.

Measurements to be Made: Eddy fluxes, aerosols, wave height spectrum, breaking waves and meteorological observations (see SK81, Section 4.2).

Data Recording: In principle, every participant should provide his own data recording system. A limited number of channels will be available on the KNMI data system (analog input between +5 and -5 V, sampling frequency between 4 and 140 Hz, depending on the channel). Data will be recorded on magnetic tape. A digital synchronization signal will be made available to all participants. There are no on-board computing facilities at MPN.

E. Humidity Experiment in the Simulation Tunnel (HEXIST)

Principal Investigators: P. Mestayer, C. W. Fairall, S. E. Larsen, J. Tillman

Purpose: HEXIST is primarily an intercomparison test for small scale turbulence instrumentation and methods to be integrated in the "turbulence package" during the major HEXOS open sea experiment. It is also intended to measure the influence of spray droplets generated by breaking waves on the humidity flux in a simulated air-sea interaction boundary layer.

Location: Grand Soufflerie (air-sea interaction simulation tunnel), Institut de la Mécanique Statistique de la Turbulence (IMST), Marseille, France.

Date: HEXIST will take place around April 1985. This will allow time for evaluation before a second test and the main HEXOS experiment in 1986. Four sets of measurements are planned: preliminary study with droplets, mean profiles, intercomparisons, and flux profiles over waves. We can completely separate the first two in time or run the four of them successively during a continuous period of occupancy of the tunnel (6 - 8 weeks).

Objectives: The major purpose of HEXIST is to test and prepare the inertial-dissipation turbulence package (Appendix 6) by intercomparing probes and evaluating their suitability for the estimation of fluxes by the dissipation method. This is PART I of the programme, and will require the major part of the participants' efforts.

We also want to take advantage of the presence in the tunnel of these sensors to gain insight into a fundamental question: what is the influence on the humidity field, and on the humidity flux, of spray droplets ejected by bursting of bubbles? This is PART II.

PART I: The purpose is to compare the adequacy of our probes to estimate the fluxes of momentum, heat and water vapour by the following methods:

- eddy correlations and cospectra
- structure functions in inertial range
- direct dissipation

This will be done at moderate (7 m/s) and high (13 m/s) wind speeds under three conditions:

- with no liquid water in air
- in the presence of spray droplets
- in the presence of fog.

Expected comparisons are the following:

Velocity	-	Hot-film/hot-wire sets (LARSEN-MESTAYER)
Temperature	-	Corrected cold-wires (LARSEN)
	-	Corrected cold-wires (MESTAYER)
	-	Precision Thermocouples (TILLMAN)

Humidity
- Cambridge dew-point units (MESTAYER)
- Dry and wet thermocouples (TILLMAN)
- Conventional Lyman-α humidiometer (TILLMAN)
- Protected Lyman-α humidiometer (LARSEN)
- Miniature Lyman-α humidiometer (MESTAYER)
- Near I-R hygrometer (TILLMAN)
- Perhaps dry and wet cold wires (MESTAYER)

I.M.S.T. owns a small mast, 90 m from the Luminy Laboratory, equipped with a light bi-vane anemometer. Comparisons of instruments mounted on this mast can be planned, although the site is hilly and dry, which is not ideal for our purposes.

PART II: It is not our intention to explore the details of the mechanisms involved in wave breaking, spray generation or droplet transport. We will restrict our effort to a simple experiment to increase our knowledge of the total humidity flux. A detailed experimental plan is being formulated. The general plan is as follows: the wind tunnel is set with some known velocity, temperature, humidity and water velocity and temperature. The following measurements will be made:

- the critical steepness (h/L) of waves generated by the "wave maker" at which waves start breaking. The value of (h/L) is close to 0.14 when there is no wind, closer to 0.10 when the wind speed is of the order of 10 m/s.

- the spectrum of the spray droplets generated by bursting of bubbles entrained by the breaking waves. A "bubble maker" will then be adjusted to obtain about the same droplet spectrum.

- estimation of profiles of humidity fluxes for waves having steepness slightly smaller than (h/L); i.e., not breaking, (a) without and (b) with the droplets produced by the "bubble maker". Use of an artificial bubble maker allows us to produce spray (ejected from breaking bubbles) continuously and, also, to estimate the effects of droplets on humidity fluxes independently of the aerodynamical effects of the white caps.

These measurements will allow us to relate the average oceanic bubble spectrum to the spectrum of sea spray droplets and their influence on the water vapour flux and the droplet flux.

Four sets of measurements are planned: preliminary study with droplets, mean profiles, intercomparisons, and flux profiles over waves. We can completely separate the first two in time or run the four of them successively during a continuous period of occupancy of the tunnel (6 - 8 weeks).

Possible additions to Part II include studies of turbulence in water (hot film sensors) and of pressure fluctuations in air (J. P. Giovanangeli, IMST), visualization of a water surface slice along the axis of the tunnel (P. Bonmarin, IMST), and measurement of bubble sizes with a scattering light probe. While not as directly related to the HEXOS questions, these studies would help to determine how well the waves and bubbles in the tunnel relate to those in the ocean.

F. HEXOS Meetpost Noordwijk Main Experiment (HEXMAX)

Co-ordinator: W. A. Oost

Purposes:

1. Measure evaporation rate by eddy flux measurements at the tip of a boom, and investigate their dependence on wind speed, sea state, and stability, for a variety of conditions typical of the fall season.

2. Test the ability of surface-layer bulk formulations to represent the measured rate of evaporation $E = C_E (\rho_w - \rho_s) U$ where C_E is an evaporation coefficient, ρ_w and ρ_s are the water vapour density at a fixed measurement height and the saturation water vapour density at the surface water temperature, and U is the wind speed at the measurement height.

3. Simultaneously observe sea state, wind stress, wave breaking, and spray droplet distributions, and investigate the dependence of evaporation rates on these quantities.

4. Compare "dissipation" estimates of evaporation from a ship and/or platform (e.g., Large and Pond, 1982) with direct eddy correlation measurements from a fixed platform.

5. Compare eddy correlation humidity flux measurements among groups operating on the Meetpost and with airborne measurements.

6. Apply corrections for flow distortion to the eddy correlation measurements of wind stress based on the HEXOS wind-tunnel study, and apply

corresponding corrections to heat flux and evaporation measurements. The relationships among bulk, dissipation, and eddy flux values for wind stress and heat flux are better known from previous experiments than the corresponding relationships for evaporation, and so can be used to test the validity of the corrections.

7. Test and evaluate several fast-response humidity sensors in marine conditions for periods of several days to several weeks.

Location:

The site of the experiment is to be the Meetpost Noordwijk, located 8 km off the coast of the Netherlands in water of 18 m depth (Appendix 1). Aircraft and ship-based observations will at times extend the coverage further from shore and into deeper water. The deepest water within 100 km is only about 32 m, while we would need 50 m depths to have fully deep-water surface wave conditions.

Date:

The experiment will be held in the fall of 1986. An initial period will be dedicated to installation and testing of equipment, with six weeks of regular data recording from mid-October until late November. This would take advantage of relatively high evaporation rates due to warm surface water and occasional strong winds.

Measurements Required:

a) From Meetpost Noordwijk

i) Background Meteorological Information

The following quantities are necessary both for the planning of measurement periods and for the interpretation of the data in terms of the overall meteorological situation:

1. wind (speed and direction),
2. atmospheric pressure,
3. air temperature (at one or two levels below and at one level above the main structure),
4. dew point temperature (at one level below and at one level above the main structure),

5. horizontal visibility,
6. cloud cover,
7. cloud type,
8. height of cloud base,
9. precipitation (type and intensity),
10. wave height and water level,
11. sea temperature, both the skin (radiation) temperature and the water temperture just below the surface and at various depths,
12. presence of slicks,
13. radiation levels (both long and short wave) (University of Washington and Argonne National Laboratory),
14. inversion height (acoustic sounder, University of Athens),
15. temperature, wind, and humidity information up to the inversion height.

The quantities (1, 3, 4, 5, 10, and 11) will be needed continuously for decisions concerning the intensive measurement periods; these and the other quantities are to be archived in accordance with WMO regulations for stations at sea (observation period and accuracy) on a continuous and/or hourly basis. As a number of quantities are to be determined visually (6, 7, 8, 12), qualified weather observers will be required. Some of the participants have agreed to log weather data and will undertake some training in order to do so. For quantities that do not fit in the WMO code, extra code-groups will be introduced. The background quantities are to be logged on a central recording system and possibly also on the recording system of a participant, if so desired.

The visibility (5), to be measured with a nephelometer or transmissometer, gives important information concerning the droplet-concentration in the air. The inversion height (14), to be determined with an acoustic sounder, will be checked against aircraft information when available.

For the quantities under (15) a radiosonde system will be considered, preferably based on LORAN-C, as the use of a radar may interfere with other sensors. The balloons of this system

are to be inflated only partially, to give detailed information on the lower part of the boundary layer. Real-time analysis and presentation of the radiosonde data will be required. In addition to this information from the measuring site itself, reports are to be obtained from the Dutch and other weather services.

ii) Turbulent Fluxes

The measurement by eddy correlation of turbulent flux of water vapour $\overline{\rho_w u_3}$ is central to the concept of the HEXOS experiment; indeed, the whole experiment plan evolved from a BIO and U of W proposal to simply measure the water vapour flux and whatever other parameters might be relevant. Eddy fluxes of heat ($\overline{tu_3}$) and momentum ($\overline{u_1 u_3}$) would be made simultaneously.

Because they rely on rather small differences between mean humidity, temperature and wind measurements at several heights, it is felt that determinations of the water vapour, heat, and momentum fluxes from profiles would be more vulnerable to flow-distortion errors than eddy flux measurements. In the limited range of working levels between the wave crests and the platform decks there would not be sufficient gradients in the mean humidity, temperature, and wind speed. Nevertheless, profile measurements will be valuable to test the modelled effects of flow distortion and to help in the interpretation of eddy correlation data.

While eddy correlation measurements from ships are generally not feasible because of motion and flow distortion problems, the 'inertial subrange-dissipation' method (Large, 1979; Large and Pond, 1980, 1981; SK81, Sections A1.3, A1.4) appears promising. This method will be tested using turbulence data from the platform and also from a ship in the immediate vicinity.

A number of groups have proposed to make eddy flux measurements in HEXOS; details of proposed participation are given in SK81, Appendix 2:

(1) Bedford Institute of Oceanography (BIO)
(2) University of Washington (U of W)
(3) Naval Research Laboratory (NRL)
(4) Argonne National Laboratory (ANL)
(5) Royal Netherlands Meteorological Institute (KNMI)
(6) Risø National Laboratory

Dissipation Measurements: Scientists from Risø, NPS, IMST and UW have drawn up a proposal to collaborate in direct and indirect dissipation measurements (Appendix 6).

Profile Measurements will be made by NRL.

While some duplication in turbulence flux measurements by each of the above three methods will be desirable, the accommodations on the platform and the load capacity of the boom are limited. The sensors themselves will create a flow distortion problem if too many are packed together at one location. In order to accommodate the interested participants it will be necessary to have groups co-operate in operating certain sets of instrumentation and to schedule crew changes during the experiment. It is unlikely that most individuals will wish to stay on the Platform for the entire experiment.

An essential element in the planning of the eddy flux measurements is the location of a measuring site on the platform at which flow distortion of the eddy fluxes can be corrected, using results from the flow distortion study (Section A) and the Pilot Study (Section D).

iii) Atmospheric Boundary Layer

In addition to studying the surface layer, the overall structure of the atmospheric boundary layer (ABL) must be considered if the aims of the experiment are to be met. Two requirements are envisaged here: routine observations of the overall structure, and more detailed studies. The former will be met by the 'background' observations (discussed above), together with data from the regular radiosonde ascents from shore

stations and acoustic sounders. In this way a continuous picture of the overall structure of the ABL (i.e., mixing depth, cloud, wind, temperature, humidity, etc.) will be supplemented by more detailed data obtained during selected periods, particularly during high winds, and on days when the UK instrumented aircraft is scheduled to fly.

b) From a Ship

1. "dissipation" estimates of evaporation, heat flux, and wind stress

2. hourly WMO meteorological observations

3. profiles of the planetary boundary layer up to the inversion height

4. oceanographic measurements of salinity and temperature

5. wave height spectrum.

The ship would at times operate in the immediate vicinity of the Meetpost, for direct comparisons, and would at other times operate in deeper water in order to investigate the effects of depth and the spatial variation of the fluxes. While a ship was considered a desirable option in the original plan for the Nordsee Platform, it becomes essential with the Meetpost accommodating fewer people and standing in shallower water.

c) From the BMO Instrumented Aircraft

This aircraft is comprehensively equipped for turbulent flux, aerosol, and meteorological measurements (see Appendix 3). In planning the HEXOS experiments the main concern is to co-ordinate with the platform and ship observations to make optimum use of available flying time, to provide comparisons with ship- and shore-based measurements, and to extend the coverage over a larger area.

The aircraft will combine profile ascents/descents, intended to reveal the mean structure of the ABL, with detailed traverses (both across and along wind) at various levels lying between the minimum operational height (about

30 m above sea level) and the top of the boundary layer. Cloud traverses would be included. These might be supplemented by 'box' patterns if it was decided to consider large-scale effects such as advection, divergence, etc., or to use these to estimate geostrophic wind. A regular program of intercomparisons with other systems would be built into the schedule.

When the ship is operating at a distance from the platform, a line between the two will be flown at several heights. The presence of fronts and other weather patterns may offer opportunities for airborne studies not directly related to the platform and ship sites and these will be included in the flight plans on a day-to-day basis.

d) From Shore

The GKSS-Research Centre meteorological group (H.-T. Mengelkamp) will measure profiles of wind speed, wind direction, temperature and dew point temperature (Table F1) in the marine boundary layer using a tethered balloon sounding system (see SK81, Section 4.4.1 and Figure 7) which has its limits at about 700 meters height and 18 m/s maximum wind speed. The resolution in the vertical varies with averaging time and number of selected heights. The maximum ascent/descent rate is 3 m/s. It may be possible to operate three tethered sondes at the same time at different heights, using a kite instead of a balloon, and the limits will rise to approximately 2000 meters height and 20 m/s maximum wind speed.

TABLE F1

Characteristics of the Tethersonde

Parameter	Sensor	Range	Accuracy
Wind Speed	Cup Anemometer	0.3 - 20 m/s	0.3 m/s
Wind Direction	Vane, magnetometer	2^{o} - 358^{o}	5^{o}
Temperature	Aspirated Thermistor	-70 - +50°C	0.2°C
Wet-bulb Temperature	Aspirated Thermistor	-20 - +50°C	0.2°C
Pressure	Aneroid Capacitance	600 - 1050 mb	1 mb

A new data acquisition system will allow on-line plotting of the profiles and calculation of common planetary boundary layer parameters.

For HEXOS in the fall of 1986, GKSS has offered to provide two or three weeks of profile measurements in the boundary layer in co-ordination with the surface layer studies. Because of limited space on the MPN, these measurements may be carried out at a nearby shore site, and will be particularly valuable during periods of onshore winds.

e) Background Data

A collection of weather maps, visual and infrared satellite photographs, sea surface temperature charts, and other available relevant data should be maintained at KNMI to form part of the HEXOS data bank.

f) Platform Occupancy

The Noordwijk platform has accommodations for 12 people, two of whom are the manager and the cook, and so the scientific party must be limited to 10. Because the platform is close to shore (only 8 km), frequent changes of personnel are possible, with those on board working longer hours for shorter periods. Boat trips would be planned about every three days, weather permitting. Changes of personnel may have to be postponed during storms. The allocation of berths is proposed as follows:

1. Chief Scientist
2. Data Manager
3. Met. Observer/Watchkeeper
4. Met. Observer/Watchkeeper
5. Eddy flux scientist
6. Spray and aerosol scientist
7. Wave and whitecaps scientist
8. Turbulence scientist
9. Extra scientist or technician (to help with problems)
10. Technician (rotate according to installation, maintenance needs).

A six-week experiment is proposed, preceded by at least a two-week period during which technicians may replace some of the scientific staff.

While the list of participants is in principle the same as before, it will be necessary to have eddy flux, aerosol, waves and turbulence measurements

each carried out by one scientist at a time, with crew changes to accommodate various individuals. The Scientific Committee will have the difficult task of insisting that each measurement group collaborate in deploying a limited quantity of instrumentation.

G. HEXOS STABLE PLATFORM EXPERIMENTS

These experiments would follow the 1986 experiment and make use of sensors (developed for HEXOS or elsewhere) for eddy correlation measurements of evaporation from a slender, stable, unmanned structure such as the BIO Stable Platform where flow distortion errors are less than at a manned platform. A depth of 50 m or more will be required for a deep-water wave regime. Radio telemetry of data to shore will limit the site to about 30 km from a shore-based receiving station.

Data will be limited to measurements of humidity flux and of necessary parameters (to be defined by the HEXOS experiments B through F) such as wind speed, air and water temperatures, humidity, sea state, and possibly aerosols. The experiment should run through a full year with data collection scheduled more frequently during storms. A ship may stand by during occasional intensive periods (perhaps 10 days, four times through the year) to make additional measurements as in the 1986 HEXMAX experiment, and aircraft measurements may also be proposed.

Because of the long lead time it is not yet appropriate to identify participants or to propose an exact date or location. One possible site is off Halifax, Canada, where high winds are encountered, particularly during winter. A subtropical or tropical site with high rates of evaporation should also be studied.

APPENDIX 1
MEETPOST NOORDWIJK

Location and Description

Meetpost Noordwijk (Measuring Station Noordwijk) is a research platform five nautical miles (9 km) from the Dutch coast off the seaside resort of Noordwijk. It is owned by Rijkswaterstaat (the Dutch Department of Public Works) and is part of the North Sea Observation Network, a co-operative undertaking of three Dutch governmental organizations.

The mean water depth at the site is 18 m; an appropriate value for the tidal amplitude is 2 m. The dimensions of the main body are 23.5 m long by 12 m wide by 7 m high.

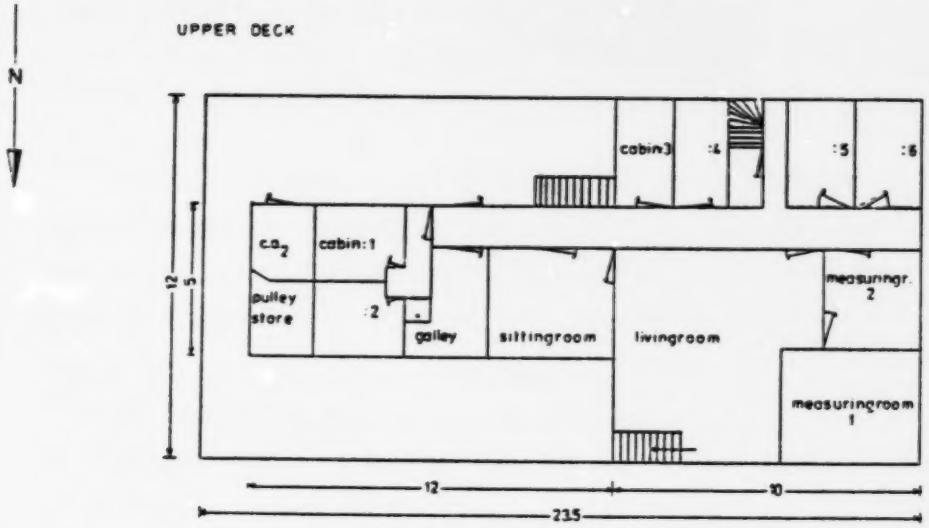
The platform is equipped with an automatic meteorological and oceanographic data system which will provide values for wind speed and direction, air temperature, humidity and pressure, sea water temperature, wave height and mean water level during the experiments. Sampling frequency is 4 Hz; standard averaging time is 10 minutes.

During October and November the prevailing winds (Table 1) are from the south and west, with the probability of Beaufort force 8 or higher winds (18 m/s and higher) being 4% in October and 9% in November. The highest observed winds, Beaufort force 11 or 26 m/s, have a probability of 0.0% in October and 0.2% in November.

Facilities

The main electrical power supply is 220 V, 50 Hz, 100 kVA. Also available is 24 V DC at a maximum of 100 A.

The lower deck is the work area (Fig. 1); note that north is down. At present the boom projects from the south side of the platform. In view of the prevailing wind, a new instrument boom to be used in the HEXOS experiments will be mounted on the west side; the exact location will be decided with the help of the flow distortion study. The main recording and control room for HEXOS will be measuring room 3 in Figure 1; this means that cables from the tip of the boom (which will be about 20 m long) to the measuring room must be at least 45 m long.



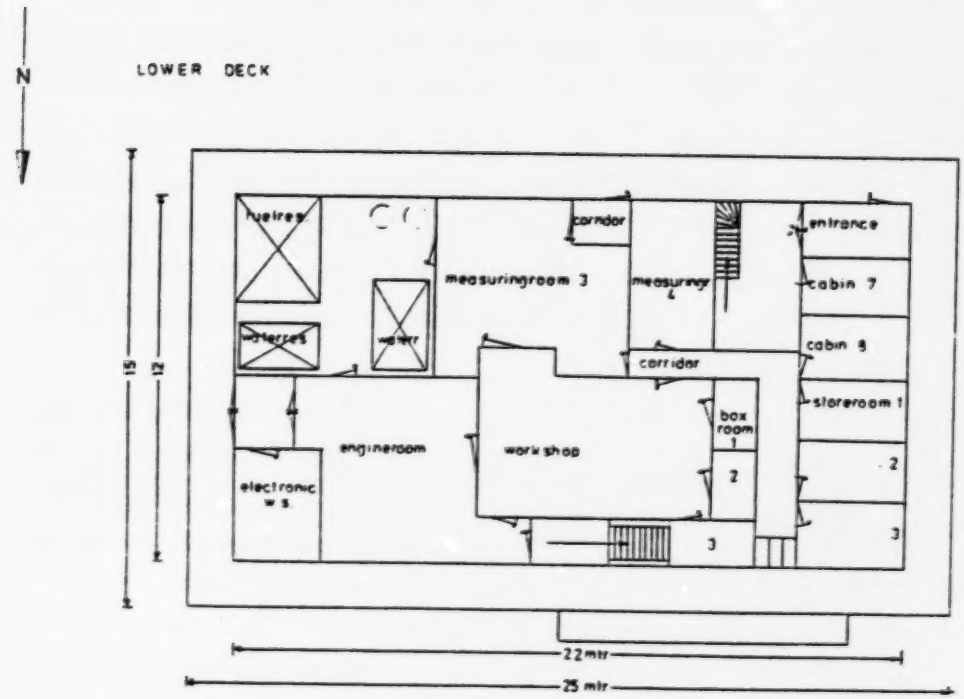


FIGURE 1. Upper and Lower Deck Plans of MPN

TABLE 1

WIND STATISTICS FOR MPN IN OCTOBER AND NOVEMBER

WINDDIRECTION AND FORCE — O C T O B E R — 1961-1970 (2480 OBS.)

PARTS PER THOUSAND (FRACTIONS OF TIME) FOR EACH DIRECTION AND FORCE

	N O R T H			E A S T			S O U T H			W E S T				
FORCE BFT	320 340	350 010	020 040	050 070	080 100	110 130	140 160	170 190	200 220	230 250	260 280	290 310	CALM OR VARIABLE	TOTAL
00	-	-	-	-	-	-	-	-	-	-	-	-	32.66	32.66
01	2.82	1.21	5.24	5.24	6.85	10.08	12.50	6.05	4.44	4.84	3.23	2.02	-	64.52
02	5.65	2.42	4.03	6.45	9.27	16.13	14.92	9.68	9.68	7.66	4.03	3.63	-	93.55
03	6.45	7.66	7.26	14.11	17.74	17.74	16.53	21.77	20.16	16.13	11.69	6.45	-	163.71
04	11.69	8.87	6.45	16.53	30.65	39.11	18.55	38.71	50.40	30.65	36.29	19.76	-	307.66
05	7.66	3.63	0.81	6.05	5.65	6.45	4.03	13.71	27.82	28.23	29.44	12.90	-	146.37
06	2.02	2.42	0.81	-	-	1.61	1.61	10.08	17.34	25.81	27.82	18.15	-	107.66
07	3.23	3.63	0.81	-	0.40	-	0.81	4.03	8.87	11.69	4.03	8.06	-	45.56
08	5.24	1.21	0.40	-	-	-	0.40	0.81	8.06	4.44	2.02	6.05	-	28.63
09	1.61	1.61	-	-	-	-	-	-	0.81	0.40	0.81	2.82	-	8.06
10	0.81	-	-	-	-	-	-	-	-	0.81	-	-	-	1.61
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	47.18	32.66	25.81	48.39	70.56	91.13	69.35	104.84	147.58	130.65	119.35	79.84	32.66	1000.00

WINDDIRECTION AND FORCE — N O V E M B E R — 1961-1970 (2399 OBS.)

PARTS PER THOUSAND (FRACTIONS OF TIME) FOR EACH DIRECTION AND FORCE

	N O R T H			E A S T			S O U T H			W E S T				
FORCE BFT	320 340	350 010	020 040	050 070	080 100	110 130	140 160	170 190	200 220	230 250	260 280	290 310	CALM OR VARIABLE	TOTAL
00	-	-	-	-	-	-	-	-	-	-	-	-	17.09	17.09
01	2.50	1.25	2.92	4.17	4.17	3.75	6.25	0.83	2.92	2.50	1.25	1.25	-	33.76
02	2.92	1.25	5.42	7.09	9.59	9.59	13.76	5.84	6.25	3.33	5.84	1.67	-	72.53
03	7.09	4.17	10.42	11.67	19.17	17.92	23.76	18.34	12.92	9.17	12.09	8.75	-	155.48
04	13.76	8.34	5.00	16.67	35.85	24.59	20.84	30.01	44.60	22.09	21.68	16.67	-	260.11
05	7.50	5.84	4.59	10.00	24.59	10.00	7.09	12.51	26.26	20.43	14.17	10.84	-	153.61
06	7.09	5.42	1.67	8.34	12.51	8.75	5.42	16.26	22.51	24.18	12.09	13.34	-	137.56
07	4.59	2.92	2.08	3.75	1.25	5.00	2.50	11.67	15.01	12.09	10.42	8.34	-	79.62
08	6.25	0.83	0.42	3.33	-	4.17	0.42	3.75	7.50	17.92	6.25	8.75	-	59.61
09	2.08	-	-	1.67	-	-	-	-	0.42	5.42	5.00	7.09	-	21.68
10	0.42	-	-	0.83	-	-	-	-	0.42	0.83	2.08	2.08	-	6.67
11	-	-	-	-	-	-	-	-	-	0.42	0.42	1.25	-	2.08
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	54.19	30.01	32.51	67.53	107.13	83.78	80.03	99.21	138.81	118.38	91.29	80.03	17.09	1000.00

Beaufort Wind Scale:

0	0-0.6 m/s	3	4.5-6.6 m/s	6	11.4-13.8 m/s	9	19.1-21.8 m/s
1	0.7-2.3 m/s	4	6.7-8.9 m/s	7	13.9-16.4 m/s	10	21.9-24.8 m/s
2	2.4-4.4 m/s	5	9.0-11.3 m/s	8	16.5-19.0 m/s	11	24.9-28.2 m/s

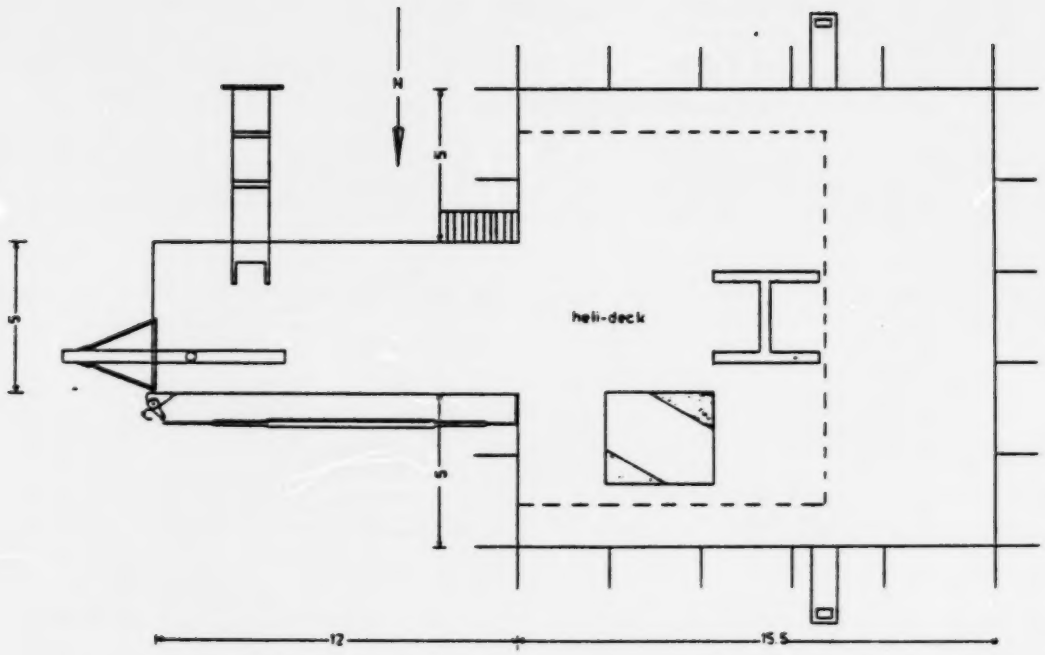


FIGURE 2. Helicopter Deck Plan of MPN

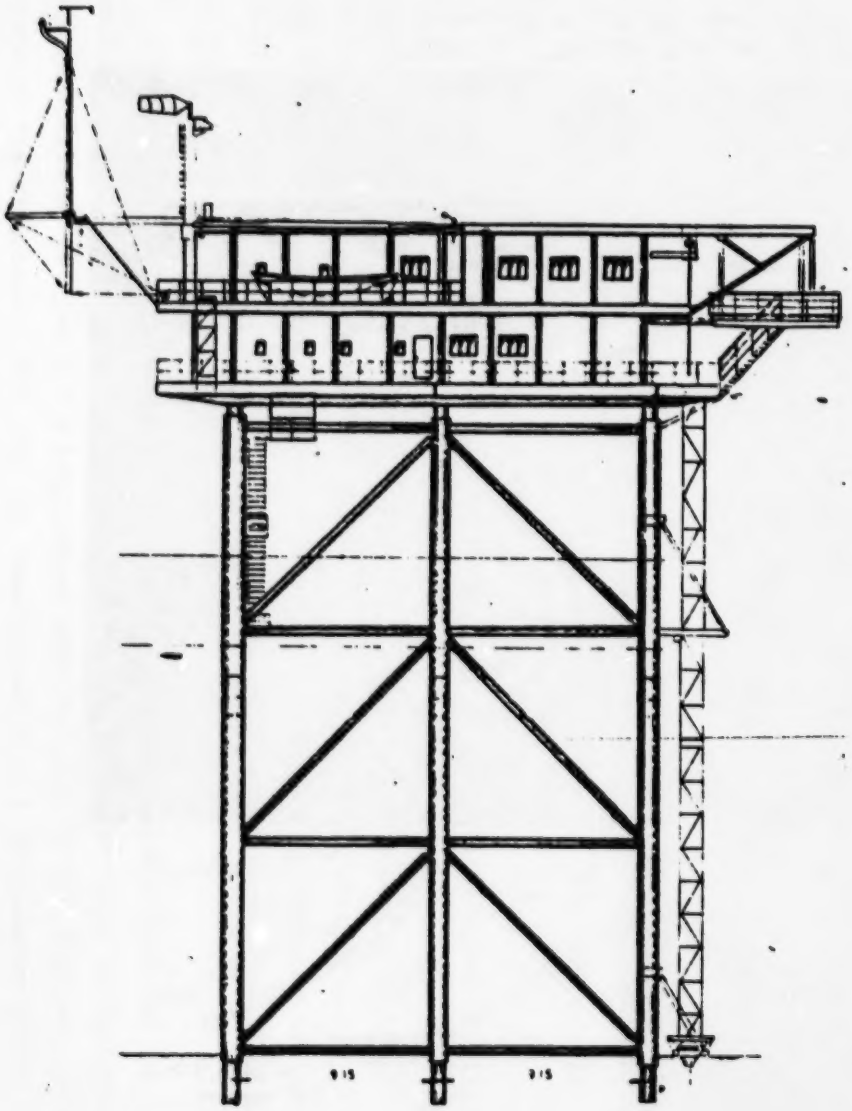


FIGURE 3. North Side Elevation of MPN

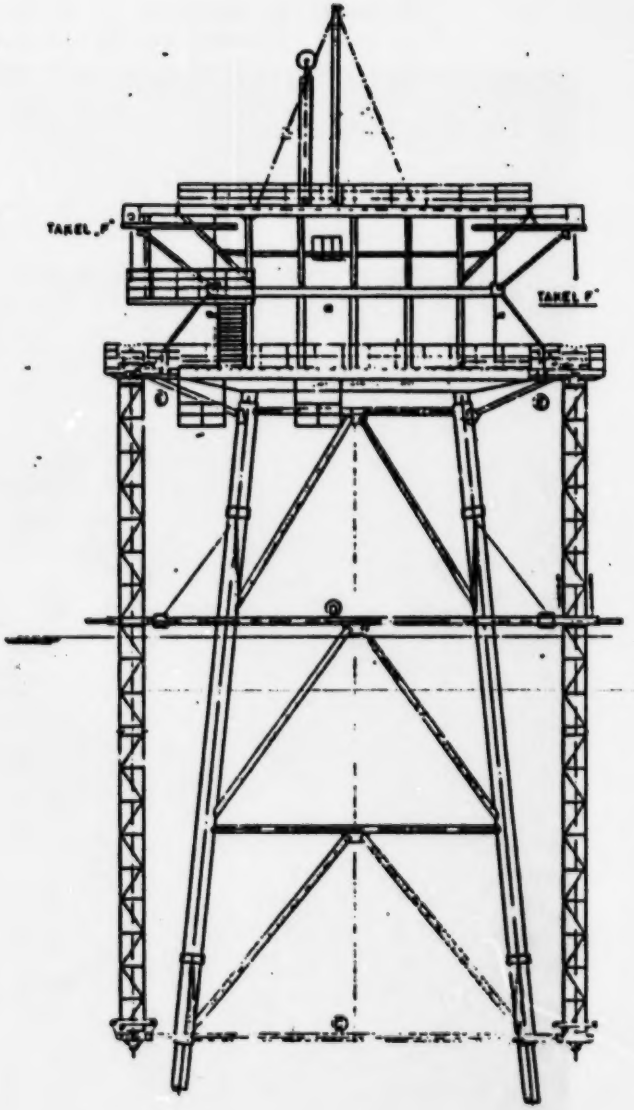


FIGURE 4. West Side Elevation of MPN

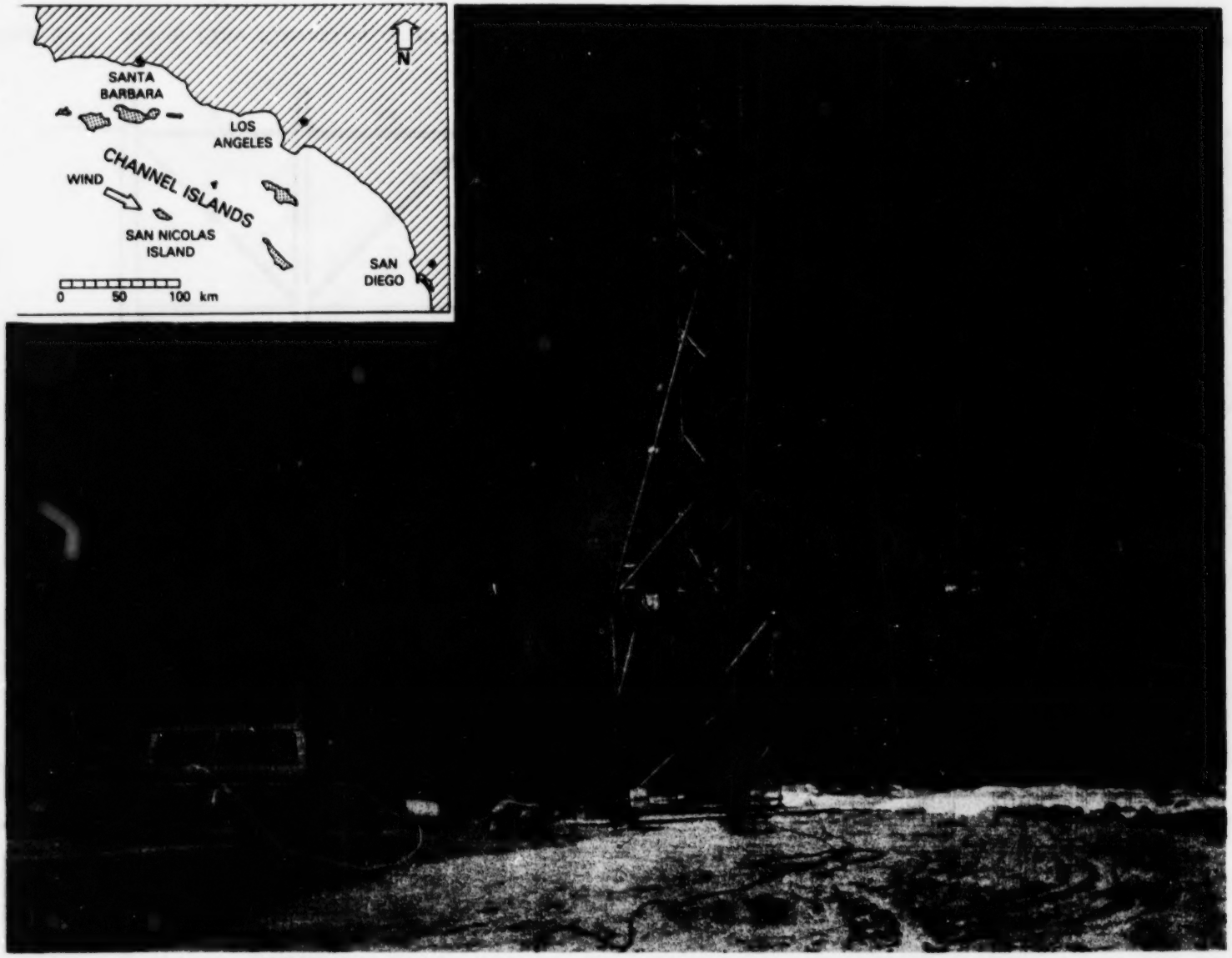


FIGURE 5. The San Nicolas Island Micrometeorological Tower.
Inset shows location of San Nicolas Island off the Coast of Southern California.

APPENDIX 2
Facilities on San Nicolas Island (SNI)

For the last four years the Naval Research Laboratory has operated a high wind marine micrometeorological research facility on the outermost point at the northwest tip of San Nicolas Island, located 120 km off the coast of southern California at 33.3°N and 119.5°W (see inset to Fig. 5). The 60 km island has been the site of a naval weather station from which surface and radiosonde observations have been routinely made for more than 30 years. A summary of the surface climatology taken from the island is available (Table 2). General experience obtained from five field operations suggests that the weather in the vicinity of the islands tends to occur in two or three-day cycles, during which conditions remain relatively uniform, and that over a span of two or three weeks a diverse spectrum of such uniform periods can be observed.

The island is owned by the U. S. Navy Pacific Missile Test Center located at Point Mugu, on the mainland, and is operated primarily as a radar tracking station. Hourly weather forecasts, observational data from surrounding islands, and other meteorological support are routinely available from the Geophysics Division weather operations centre located at Point Mugu. The island has a 2.6 km runway, twice daily weekday air service from the mainland, monthly barge service, food and housing facilities for visitors, recreational facilities, hardline electrical power to the experiment site, commercial telephone circuits to the mainland, and transportation (trucks, vans, etc.) is available on the island.

The experimental site and micrometeorological tower are designed to withstand the high wind and sea state to which the area is routinely subjected. The tower (Figure 5) is located approximately 20 m from the extreme highwater mark on the outermost point of the island's major promontory. Both point directly into the prevailing northwest wind. The experimental site is situated at the end of a low-profile, narrow, pointed peninsula which has a mean slope of 1:20 and which extends 1.5 km upwind of the island's main body.

The specially designed micrometeorological tower is 19.1 m high and is constructed of 7.5 cm diameter welded tubular aluminum. The tower is designed to accommodate up to five 6.7 m long sensor arms designed to minimize any upwind effect of the structure. The arms are constructed of 4.5 cm diameter welded

tubular aluminum and can be situated at any combination of 1.5 m height intervals on the upwind side of the tower. The arms are hinged halfway forward to allow easy access to the sensors from within the safety of the main tower structure. Electronics and personnel are typically housed in a 80 m^3 environmentally controlled mobile field shelter temporarily parked near the base of the tower.

Further information on the SNI facility is given by Blanc (1981).

TABLE 2

WIND CLIMATE AT SAN NICOLAS ISLAND

San Nicolas Island, 1947 to 1972**									
Month	Most Frequently Observed Direction			Mean Speed All Directions (Knots)	Peak Gusts		Observations With Speed Greater Than 21 Knots (Percent)	Percent of Observations	
	Direction	Mean Speed (Knots)	Observations (Percent)		Speed (Knots)	Direction		Calm	Wind From WNW, NW, NNW
January	NW	12	28.2	9	52	WNW	3.5	7.0	49.1
February	NW	14	31.9	10	40	NW	5.7	6.4	53.4
March	NW	15	38.5	12	43	WNW	9.8	3.7	62.7
April	NW	15	42.2	12	42	NW	10.5	4.0	65.5
May	NW	16	46.8	12	42	WNW	13.0	3.5	69.2
June	NW	14	43.2	11	45	WNW	7.1	7.2	65.0
July	NW	13	42.3	10	45	NW	3.5	4.9	64.6
August	NW	13	44.5	10	41	WNW	3.0	5.7	67.0
September	NW	13	39.8	9	39	WNW	3.7	6.5	62.9
October	NW	12	31.9	8	41	NW	3.5	6.5	53.7
November	NW	12	28.0	9	41	WNW	5.2	7.6	51.0
December	NW	12	29.3	9	42	NW	3.9	7.2	49.9
Year	NW	14	37.4	10	52	WNW	6.0	5.6	59.7

TYPICAL WATER DEPTHS NW OF SAN NICOLAS ISLAND

Upwind Distance	km	0.1	0.2	0.5	1	2	5	10	20	50
Water Depth	m	2.0	4.0	10.0	20	30	50	80	100	1000

APPENDIX 3
British Meteorological Office C-130 Hercules Aircraft

This aircraft, based at Farnborough, England within easy range of MPN, is a complex atmospheric laboratory capable of operating for long periods (up to 10 hours) in the lower levels of the atmosphere. The basic parameters measured by this aircraft are summarized in Table 3, together with types of instruments used and their accuracies. In addition, the aircraft has available:

3 cm weather radar
Pollak counter (a cloud condensation nucleus counter)
Knollenberg ASSP (aerosol size spectrum probe)
2 two-dimensional optical array probes (one for cloud droplets, the other for precipitation particles)
holographic camera
Johnson-Williams liquid water content meter
Various types of cameras, air sampling facilities and a gas chromatograph.

Figures 8 and 9 are schematic drawings of the aircraft showing the location of the various instruments. This aircraft is capable of providing a very detailed picture of the atmosphere including turbulent structure and aerosol/droplet spectra. Further details are given by Crabtree and March (1981).

The C-130 aircraft will combine profile ascents/descents, intended to reveal the mean structure of the ABL, with detailed traverses (both across and along wind) at various levels lying between the minimum operational height (about 30 m above sea level) and the top of the boundary layer. Cloud traverses would be included. These may be supplemented by 'box' patterns if it is decided to consider large-scale effects such as advection, divergence, etc., or to use these to estimate geostrophic wind.

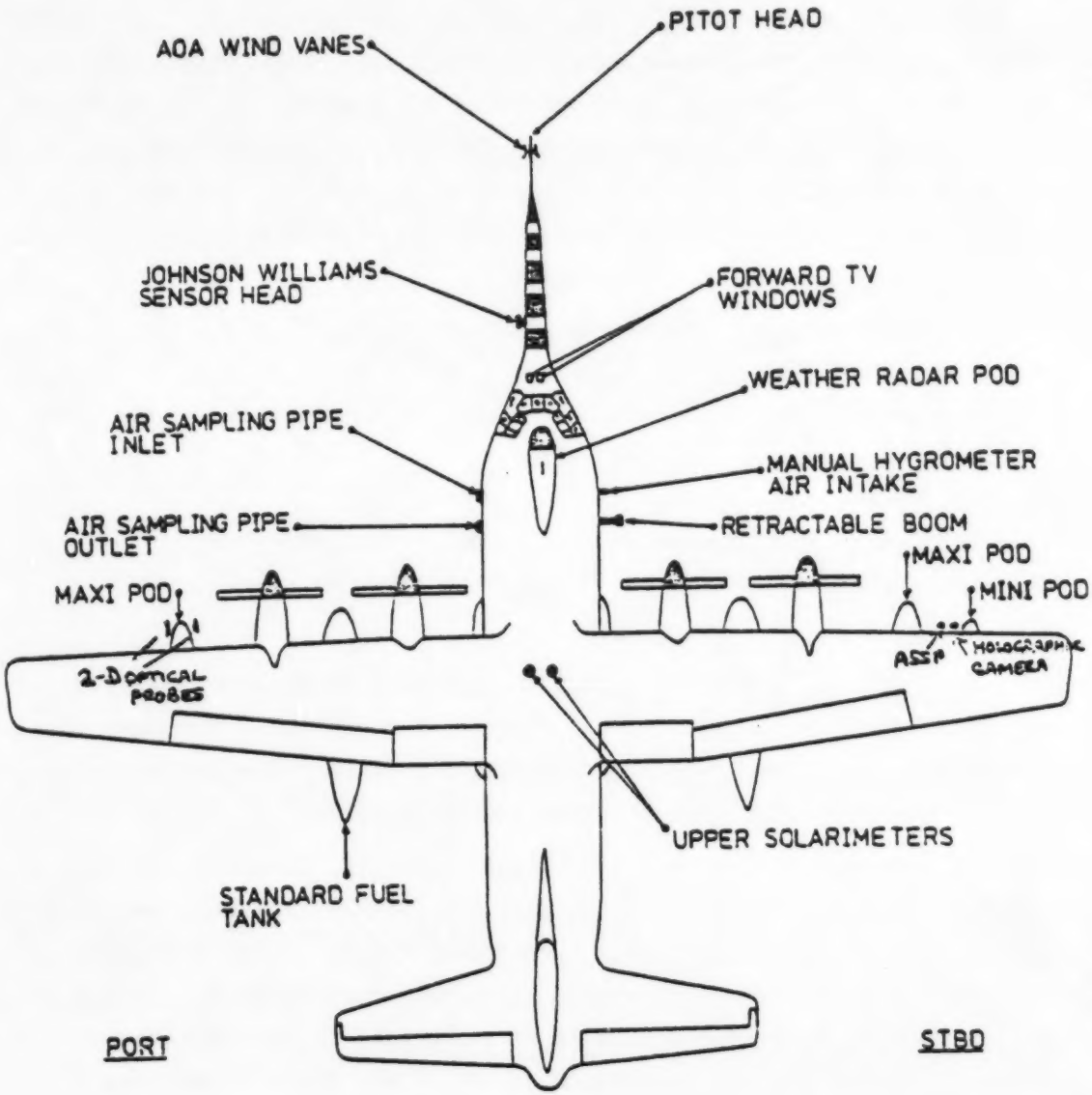


Figure 6. MRF Hercules XV 208 - Location of Instruments Viewed from Above

BASIC PARAMETERS MEASURED ON MRF HERCULES

Table 3

Parameter	Symbol	Absolute Accuracy[1]	Resolution	Sampling Frequency[2] (HZ)	Equivalent Distance Along Track(m)	Primary Instrumental Source	Instrument Type and Manufacturer
Horizontal wind components	u	~ ±0.4m/s	0.0?m/s	40	2.5	Pitot-static system	Boom—Rosemount 855BL Static Transducer-Rosemount 1301A4B Dynamic Transducer-Rosemount 1301D?
	v	~ ±0.4m/s	~ 0.05m/s	40	2.5	Inertial platform Doppler radar Navigation aid Vane (sideslip)	INS - Ferranti Miniature Type B Decca Doppler Type 62M DECCA or LORAN
Vertical wind component	w	±0.1m/s (for W.C)	0.03m/s	40	2.5	Pitot-static system Inertial platform Vane (attack)	
Temperature a)	T	±0.2K	0.006K	20	5	De-iced platinum resistance thermometer Pitot-static	Rosemount 102BL102BK
b)		±0.2K	0.1K	4	25	Non-de-iced Pt resistance thermometer Pitot-static system	Rosemount 102E2AL
Dew/frost point temperature	T_d	±0.3K[3]	0.1K	4	25	Cambridge automatic Hygrometer [4]	Cambridge Systems Model 137
Specific humidity	q	±0.15g/kg	0.02g/kg	40	2.5	Refractometer Cambridge hygrometer Rosemount thermometer Pitot-static system	MRF + Appleton Laboratory
Sea surface temperature	Ts	±0.3K	0.1K	4	25	Barnes PRT - 4 (modified)	Barnes + MRF modification
Radiation a) short-wave b) long-wave	 Rs Rl	 ±2W/m^2 ~ ±10W/m^2	 0.7W/m^2 2W/m^2	 1 1	 100 100	 Eppley pyranometer Eppley pyrgeometer	 Eppley PSP Eppley PIR
Pressure	P	1mb[5]	0.5mb	20	5	Compensated static ports (part of pitot-static)	
Geometric altitude	Z	1% or 1m	0.8m	2	50	Radar altimeter	Honeywell AN/APN-171(V)

Notes

1. Accuracy is quoted for straight and level flight in relatively undisturbed conditions over the sea.
2. The sampling frequency is usually greater than the frequency of the signal to which the instrument will respond properly (by a factor of about 2-10).
3. Accuracy quoted is for temperatures above freezing point.
4. There is also a Dobson-Brewer manual hygrometer with comparable accuracy.
5. A relative accuracy of ± 0.1mb can be obtained for average values over one minute.

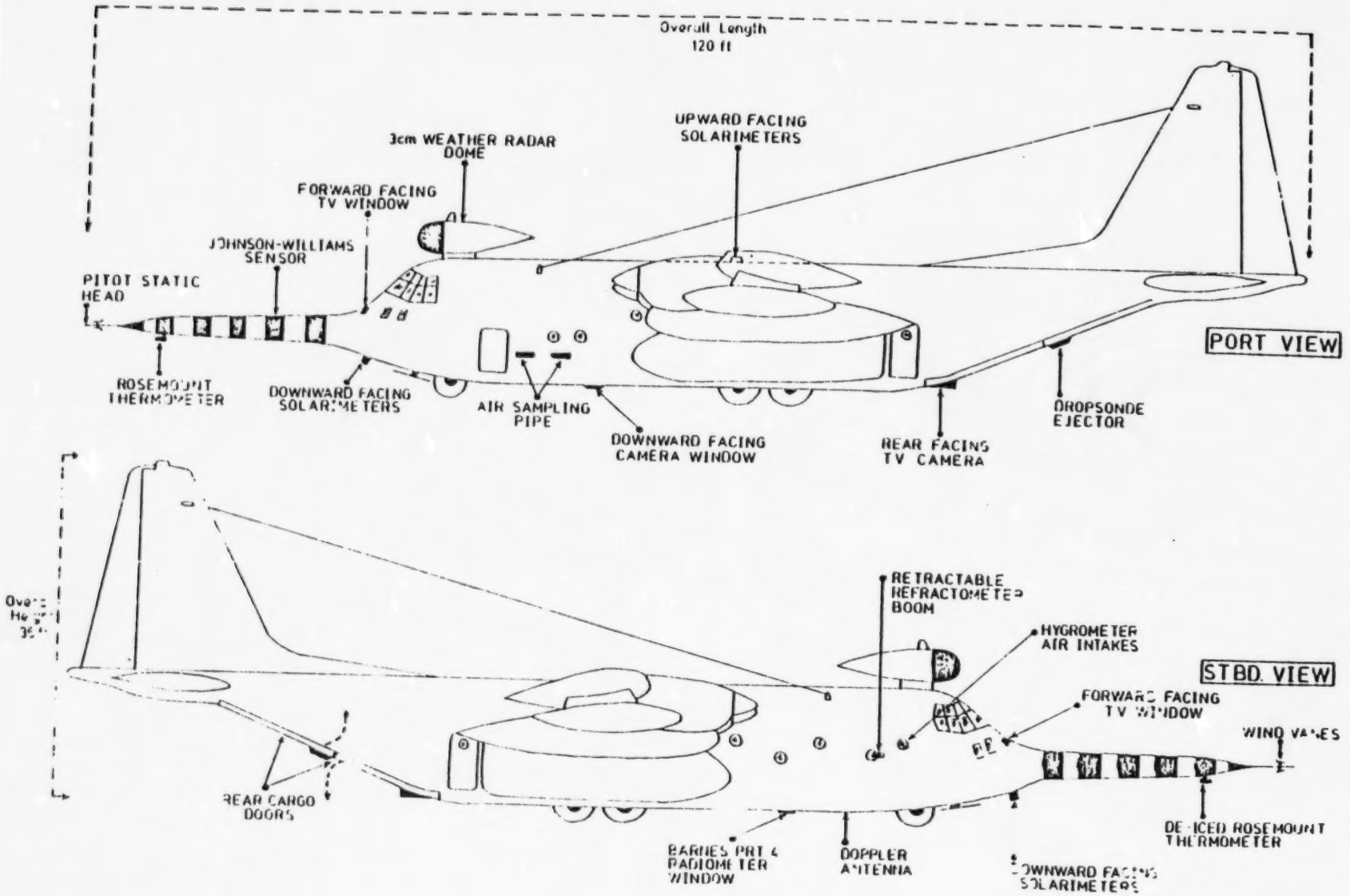


Figure 7. MRF Hercules XV 208 - Location of Instruments (port view and starboard view)

APPENDIX 4

RV ACANIA

The RV Acania, operated by the U.S. Naval Postgraduate School, Monterey, California with funding from the Oceanographer of the U.S. Navy, has been developed into a floating laboratory for marine meteorology and air-sea interaction studies (Schacher et al, 1980). She will participate in the San Nicolas Island Pilot Experiment in 1984 and possibly in the main experiment HEXMAX in 1986.

She is 39 m long, with a 4 m bow mast and a 22 m forward mast which telescopes to facilitate instrument installation (Figure 6). There are two laboratory spaces for instrument readouts, etc., and berths for 10 scientists. The permanent onboard systems are listed in Table 4.

Data logging is based on a Hewlett Packard 9825 or 9835 desktop computer and HP 3052A data acquisition system. About 20 of the 40 input channels are occupied by routinely used sensors. The HP 3455A digital voltmeter used has a resolution of six significant figures, and the sampling interval is 1.2 to 2.2 seconds.

A centralized slow analogue data logging system will be provided by NRL and NPS. Individual investigators are requested to provide inputs for the system. While the NPS onboard data acquisition has more than adequate capability to accommodate all slow-analogue requirements, faster data acquisition requirements (e.g., spectra) must be provided by the individual investigator. More sophisticated data processing (e.g., eddy-correlations, spectra, particle spectra) will be handled separately.

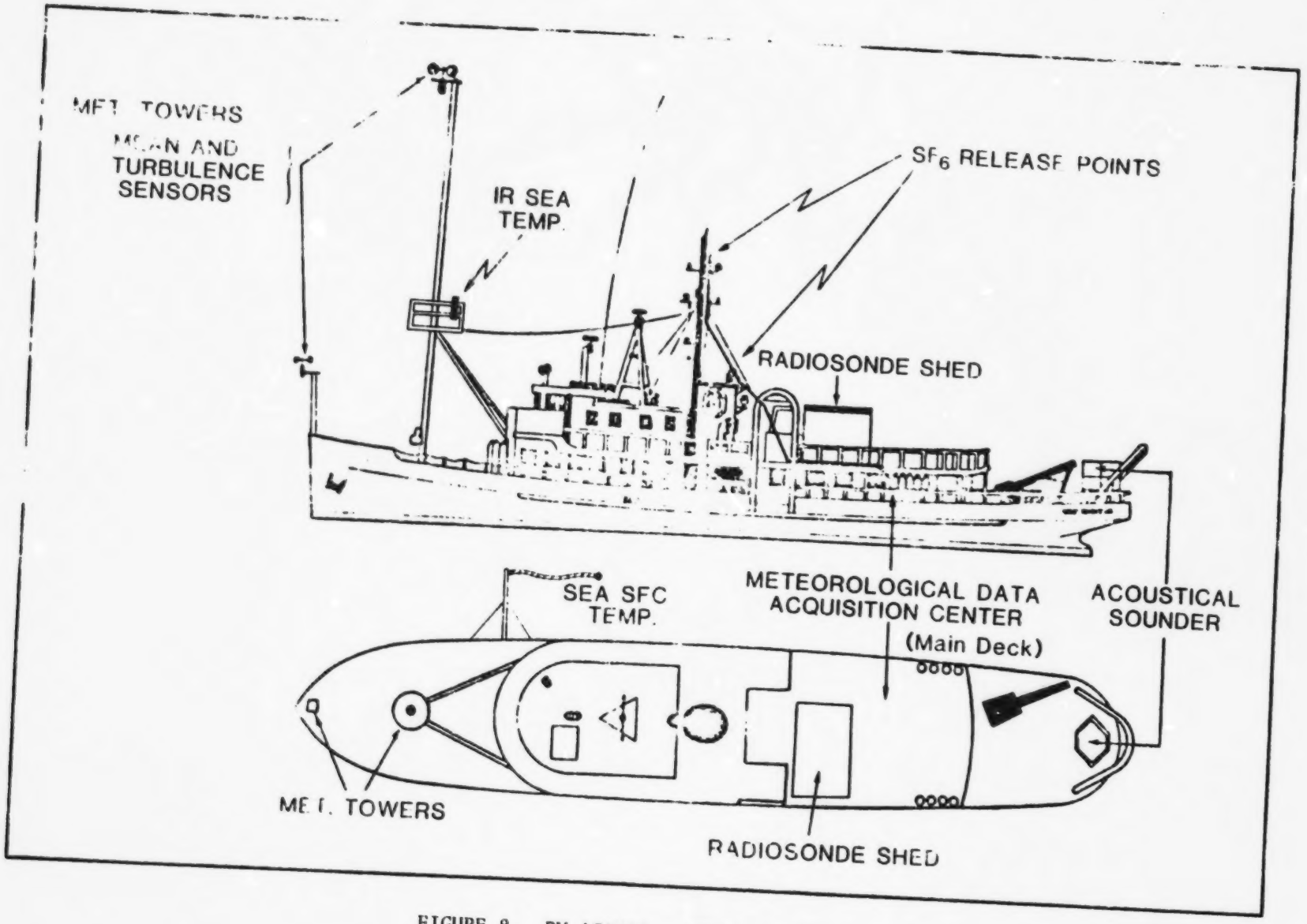


FIGURE 8. RV ACANIA. (Ship is 39 m long.)

TABLE 4

Shipboard Measurement Capabilities, RV Acania

Measurement	Sensor
Radiation	Eppley radiometers
Sea Surface Temperature	Floating platinum thermometer and IR radiometer
Mean Surface Layer:	
Wind (speed, direction)	Cup anemometer, vane
Temperature	Aspirated platinum thermometer
Humidity	Dew cell (cool mirror)
Turbulent Surface Layer:	
Wind	Hot films
Temperature	Resistance wires
Humidity	Lyman-Alpha
Inversion Height	Acoustic sounder
Temperature and Humidity Profiles	Radiosonde
Aerosols	Optical Counters

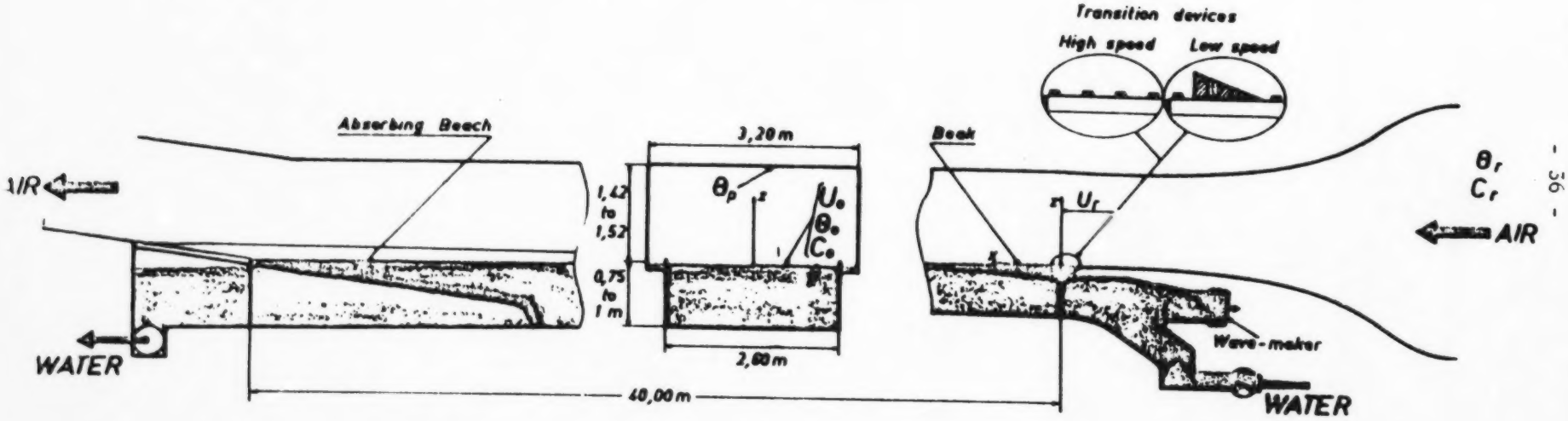


FIGURE 8. THE IMST SIMULATION TUNNEL

APPENDIX 5
THE IMST SIMULATION TUNNEL

The Grand Soufflerie, operated by the Institut de la Mécanique Statistique de la Turbulence (IMST) in Marseille, France, was specifically designed to simulate air-sea interaction processes. The size of the tunnel test section is 1.5 m high by 3.2 m long (Figure 8). The boundary layer thickness is about 70 cm. It develops over a fetch of 36 m. The ranges of adjustments are as follows:

- air speed, 0 to 14 m/s; temperature, +3 to +40°C; humidity, 0 to 100% (controlled by cold and hot exchangers and two sets of vapour injectors);
- tunnel ceiling temperature can be controlled;
- water speed, 0 to 20 cm/s; temperature, +3 to +40°C; wavemaker frequency, 0 to 2 Hz.

The usual probe supports are light 2 cm thick shaped tubes passing through the tunnel ceiling and borne by supports with vertical displacement remotely controlled. A tubular-truss carriage has recently been installed on rails fixed to the walls of the test section. It is at present actuated at constant speed, up to 1 m/s. There is not yet any specific fixed or moving probe support on it. Light probe supports can also be connected to a "wave follower" that maintains them at constant height over the water surface.

The digital system which records and analyses the turbulence data is in the process of renovation. At the time of the experiment the processing performance will certainly be superior to that of the present H.P. 2100 A, but recording performance will be of the same order as now:

- 8 protected lines from tunnel test section to A/D converter;
- 14 bits plus sign bit;
- 8 channels;
- maximum sampling frequency = 49 kHz/number of channels used (2 to 4 times faster expected by 1985);
- maximum continuous storage (on disc) 1.2×10^6 samples (20 times larger expected), then samples are dumped on tapes (16 bits, 800 bpi);
- delayed processing with a real time executive operating system.

The laboratory is equipped with two 7-track analog recorders (AMPEX and

SCHLUMBERGER, 20 kHz, 49 db).

Electrical supply is available at 110 v, 220 v, and 380 v triphase, all at 50 Hz; and a set of small adjustable units supply continuous DC voltages.

APPENDIX 6

PROPOSAL FOR FLUX MEASUREMENTS SIMULTANEOUSLY BY THE EDDY CORRELATION AND THE DISSIPATION METHODS DURING HEXOS

by C. W. Fairall, S. E. Larsen, P. G. Mestayer, and J. E. Tillman

A.6.1 Introduction

Turbulent fluxes of momentum, heat and moisture at the sea-air interface are important in numerous aspects of oceanography and meteorology. There are four standard techniques for calculating these fluxes from atmospheric measurements:

1. direct covariance (eddy correlation);
2. inertial subrange dissipation and direct dissipation;
3. profiles, and
4. bulk aerodynamical methods.

The dissipation type methods are a good compromise, being insensitive to platform motion (unlike the covariance method) and relatively insensitive to platform distortion of the air flow (unlike the covariance and profile methods).

The inertial-dissipation method (which relies on the Kolmogorov constant) and the direct dissipation method differ only in the method used to obtain the dissipation rates. Turbulence balance expressions for the variances are then solved for turbulence scaling parameters and, hence, the surface fluxes. A co-operative investigation by Risø National Laboratory, the Naval Postgraduate School (NPS), the Institut de Mecanique Statistique de la Turbulence (IMST), and the University of Washington (UW) is planned in the HEXOS program.

A.6.2 Measurements to be Made

The primary area of interest will be the use of eddy correlation and structure functions (not direct dissipation data) to infer surface fluxes. Scientists from Risø, NPS, IMST and UW will co-operate in providing instrumentation, experimental participants, calibration, and data analysis. Many relevant measurements (e.g., droplet spectra, invers ion height) will be made, but the following are planned by the "dissipation" group:

a) Eddy Fluxes and Variances

For these parameters a number of different sensors are available:

i) A newly developed Risø-propeller anemometer (u, v, w; U, V, W) (SK81, Section A1.12);

ii) Kaijo Denki three-component DAT 300 sonic anemometer especially developed for large velocities (u, v, w, θ; U, V, W, Θ);

iii) Humidity (q) will be measured by Lyman-α humidiometer, wet/dry thermocouples or an IR hygrometer under development in a joint project between the University of Washington and Risø (SK81, Sections A1.11 and A2.5);

iv) In addition to (ii), temperature (θ) measurements may be performed by use of microthermal sensors.

As the planning of the experiments proceeds, it will be determined which groups of sensors will be included.

b) Structure Functions

Inertial subrange turbulence will be measured with microthermal sensors (θ), hot wires (u), and Lyman-alpha (q) systems. The structure functions will be calculated using spectral and filter-variance methods, and the temperature structure function C_T^2 will also be measured directly. The sonic anemometer-thermometer will be used in an effort to measure C_T^2 without the salt contamination problems associated with microthermal sensors (Schmitt et al., 1978; Fairall et al., 1979).

c) Dissipation Rates

Direct measurements of the dissipation of turbulent energy ε, and of the dissipation of temperature fluctuations, N_θ, will be made from the time derivatives of velocity and temperature measured at very high frequencies (up to about 1 kHz). State-of-the-art hot-and cold-wire sensors will be required to obtain the necessary noise, frequency, and spatial resolution characteristics (Larsen and Busch), 1976); Mestayer and Chambaud, 1978; Larsen and Højstrup, 1982). The dissipation of humidity fluctuations N_q will be measured using a miniature Lyman-α humidiometer, which is currently being tested at IMST.

d) Mean Variables

i) U: cup anemometers, sonic anemometer;

ii) Θ: Platinum resistance sensors and quartz oscillator sensors in silvered glass thermos aspirators;

iii) T_d (the dewpoint temperature): cooled mirror dew cell, wet-dry bulb psychrometer;

iv) Sea surface T: Barnes PRT-5 IR radiometer, immersed platinum sensor.

e) Data Acquisition

i) FM magnetic tape recorders;

ii) Strip chart recorders;

iii) Computer-controlled data scanner. Most turbulence variables will be pre-processed (filters, RMS units, etc.) to allow slow analogue-digital conversion.

iv) Computer interfaced real time spectrum (dual input) analyser.

The simultaneous measurement of fluxes, structure functions and dissipation rates over the ocean will provide a unique data set. Because of the influence of the platform on the air flow, no attempt will be made to measure all of the terms of the variance budget equations.

It will probably be impossible to obtain direct measurements of dissipation during the weather conditions of most interest for the HEXOS project (strong wind). Direct dissipation measurements will be possible during periods of light and moderate winds.

Tentative Schedule

The "dissipation" group plans to participate in the Meetpost Noordwijk experiments in the fall of 1986, and the measurements described above are planned for that experiment. However, some members of the group will test equipment during the experiment in 1984 at San Nicolas Island. Furthermore, the group plans to perform a detailed study of the influence of droplets on the turbulent fluxes in the IMST Simulation Tunnel (see Section E).

APPENDIX 7

HEXOS WORKSHOPS AND COMMITTEE MEETINGS

A workshop of field participants is proposed in 1984 to co-ordinate details of the scientific plan and field operations. This would be held at KNMI in summer or early fall when weather conditions are most likely to favour a visit to the Meetpost Noordwijk.

A second workshop will be held in 1987 to present preliminary analyses and assessments of the data. This meeting should be held at the location of the HEXOS data bank.

A special session will be planned at a suitable international scientific meeting about two years after the main experiment in order to present the results in a co-ordinated way. It is hoped that several HEXOS papers can be submitted to appear together in an appropriate journal.

HEXOS Scientific Committee

The Scientific Committee consists of S. D. Smith (Chairman), K. B. Katsaros, and W. A. Oost. This committee will correspond regularly and meet once per year to co-ordinate and revise the programme, maintain contact with participants, make applications for funding, and review scientific progress. The following schedule of committee meetings is proposed:

August, 1983:	Hamburg, during or immediately following IUGG meeting.
1984:	KNMI, deBilt (summer or early fall, preceding Meetpost Noordwijk pilot experiment), including meeting of field participants.
1985:	BIO, Dartmouth, or U of W, Seattle.
Early 1986:	KNMI, deBilt.

APPENDIX 8

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